U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
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May 4, 2001 F/SWC2:RWB:FLF
CR0103-1.RWB

CRUISE REPORT

VESSEL: *Townsend Cromwell*, Cruise 01-03 (TC-266)

CRUISE PERIOD: 29 March-15 April 2001

AREAS OF OPERATION: North Pacific, lee side of the Island of Hawaii (Kona coast), Island of Oahu (off southern coast), and Cross Seamount (Fig. 1)

TYPE OF OPERATION: Deployed and retrieved longline gear in an effort to catch swordfish, blue sharks, and bigeye tuna for placement of archival tags and pop-up satellite tags (PSATs).

ITINERARY:

29 March	Embarked scientists Richard Brill, Dan Curran, Muno Fraguso, Kirstin Fritches, David Itano, Tom Kazama, Mike Musyl, and Eric Warrant. Departed Snug Harbor 1500. Transited to area off the leeward coast of the Island of Oahu. Began setting longline gear in an effort to catch swordfish, blue sharks, and bigeye tuna for the placement of archival tags and pop-up satellite tags.
30 March	Retrieved longline gear. Departed for north Pacific to continue longline operations.
31 March-5 April	Arrived north Pacific fishing area and continued longline operations.
6-8 April	Departed fishing area due to deteriorating weather conditions and transited south to Cross Seamount.
9-11 April	Arrived Cross Seamount and continued longline operations to catch bigeye tuna and blue

	sharks for tagging. Deployed all remaining archival tags on bigeye tuna.
11 April	Completed operations at Cross Seamount. Departed due to deteriorating weather conditions. Transited to lee side of the Island of Hawaii (Kona coast)to continue longline operations targeting blue sharks.
12 April	Arrived lee side of the Island of Hawaii and continued longline operations to catch blue sharks for tagging.
13-14 April	Finished deployment of PSATs on blue sharks. Began transit to Snug Harbor.
15 April	Arrived Snug Harbor. All disemarked. End of cruise.

MISSIONS AND RESULTS:

A. Capture swordfish for placement of archival tags.

Placed PSATs on 8 swordfish.

B. Capture blue sharks for placement of archival tags and sample blood to determine biochemical indicators of delayed mortality.

Placed PSATs on 14 blue sharks, and obtained blood samples from 12 of these animals for measurement of biochemical predictors of post-release mortality.

C. Capture bigeye tuna for placement of archival tags.

Captured and placed archival tags into 10 bigeye tuna and opportunistically into one juvenile swordfish.

D. Opportunistically capture other sharks and large pelagic fish species for attachment of PSATs.

Captured 2 large (estimated body mass > 75 kg) yellowfin tuna and attached PSATs to them prior to being released. Captured oceanic white tip shark and attached PSAT to it prior to being released.

E. Collect tissue samples for ongoing physiological/biochemical studies of tunas and billfishes and fin samples of sharks.

1. Took tissue samples from 4 bigeye tuna, 5 yellowfin tuna, and 5 swordfish that were either too small or too badly injured to have archival tags or PSATs attached.

2. Took tissue samples from 1 escolar, 2 ono, 2 striped marlin, and 5 skipjack tuna.

F. Conduct experiments on vision in tunas and billfishes using isolated retinas and standard physiological techniques.

A detailed description of the results of these experiments are presented in the attachments (Appendix I).

RECORDS:

The following forms, logs, charts, and data records were kept and given to the Honolulu Laboratory upon termination of the cruise. These include all data captured onto computer storage media during the cruise. All the records are filed there unless indicated otherwise in parentheses.

ADCP DOPPLER ping data files
SEAS system data files
Deck Log - Weather Observation Sheet
Machine Operations Log (NOAA)
Project Area and Operations Chartlets
Station Number and Activity Log
Special Time and Attendance Report (filed with Administration)

SCIENTIFIC PERSONNEL:

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Daniel Curran, Fishery Biologist, Joint Institute for Marine and Atmospheric Research (JIMAR), University of Hawaii (UH)
Muno Fraguso, Biological Technician, Queens University
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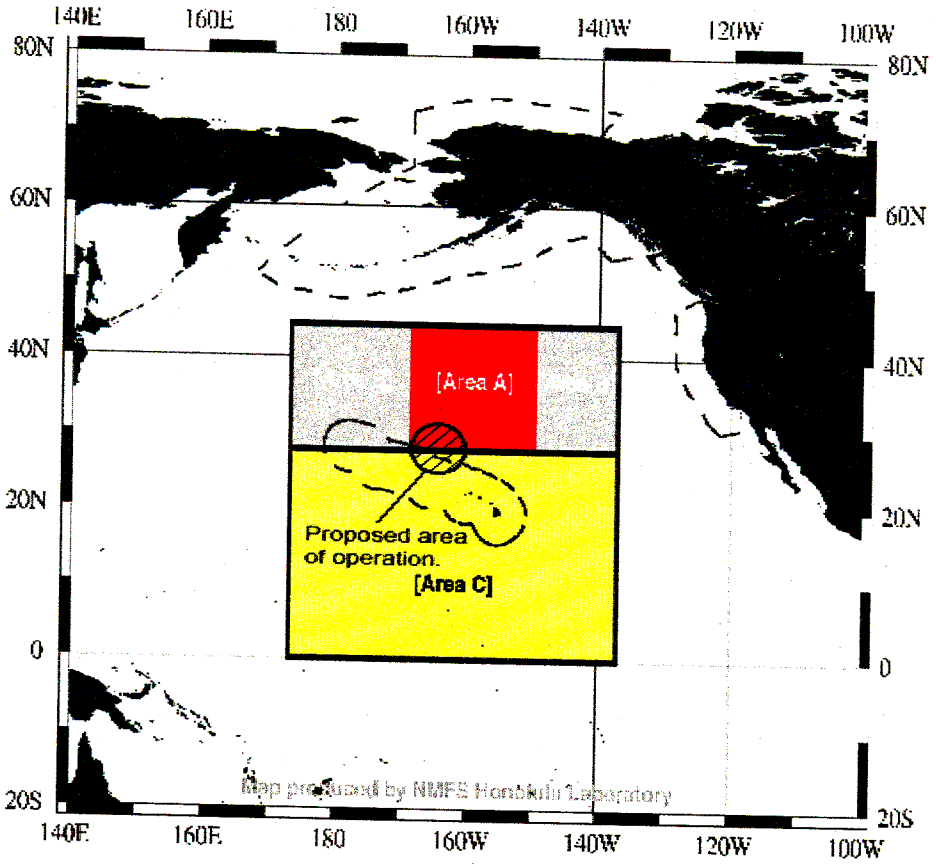
Michael K. Musyl, Cooperating Scientist, JIMAR, UH
Eric Warrant, Cooperating Scientist, University of Lund

Submitted by: _____
Richard W. Brill
Chief Scientist

Approved by: _____
R. Michael Laurs
Director, Honolulu Laboratory

Attachments

Fig 1. Approximate proposed area of operation. Note, longline operations will occur in areas (shown in color) where commercial longline fishing is currently restricted.



Visual Performance in pelagic fishes: new discoveries in the perception of colour and motion in billfishes and tunas

Dr. Kerstin Fritsches (University of Queensland, Australia)
Dr. Eric Warrant (University of Lund, Sweden)

Introduction

Large ocean predators like billfishes and tuna rely heavily on vision to catch their prey. These powerful animals can swim tremendous distances, often at very high speed and in very deep water, in search for prey. A visual world as dim and cold as that of pelagic predators places considerable strain on the evolution of good vision especially for fast swimming species. Exactly how well do these animals see? How have they overcome restrictions of cold water and dim light to enable them to catch their prey? Due to the extreme difficulty in obtaining live specimens – especially billfishes – these questions have so far remained unanswered. Following a highly successful cruise on the NOAA ship *Townsend Cromwell*, we are pleased to report fascinating new insights into the visual capabilities of pelagic fishes. Beyond the purely scientific, our results also have implications for current fishing practices.

Optics of huge pelagic eyes imply active predation in very dim light

To see well in dim light, one strategy is to have a very large eye with a large pupil. In this respect we could show that the eyes of tuna and billfishes are ideally adapted for this task. For instance, in the largest swordfish we studied (ca. 2.5m body length) the eyes were 9 cm wide and the pupils measured almost 4 cm across. According to our new theoretical model of visual performance, and optical measurements (figure 1) we made on the *Townsend Cromwell*, we can predict that nocturnal and deep-water predators like swordfish and big-eye tunas are efficient visual hunters in dim light. The model also allows us to simulate the visual behaviour of these fishes and predict their ability to capture fast-moving prey in dark water.

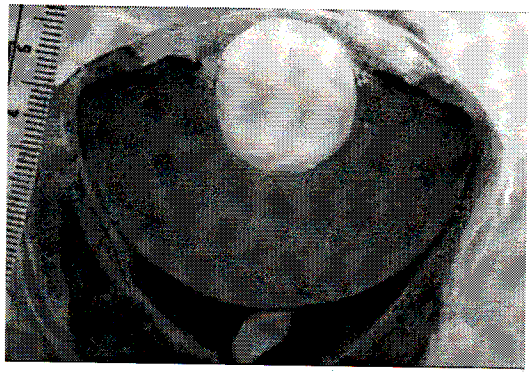


Figure 1: Frozen cross section of a bigeye tuna eye, collected on board the *Townsend Cromwell*. From these images we will be able to determine the internal dimensions of the eye which will help our understanding of the optical adaptations of the pelagic eye.

Significant variations in the speed of vision between different species of pelagic fishes

For fast swimming hunters in dim light, the optimal speed of vision poses a dilemma since fast vision requires high light intensities while slowing down the temporal resolution of the eye in dim light will blur the image of prey items moving at speed. The speed of vision is commonly determined by measuring the response of the eye to individual pulses of light from a flickering light source. Flicker fusion is reached at a frequency when the eye loses its ability to resolve the individual pulses of the light source. During our research expedition we succeeded in determining the Flicker Fusion Frequency (FFF) of a number of pelagic fishes including the swordfish, yellowfin tuna and bigeye tuna. Fast swimmers such as the swordfish and the bigeye tuna showed surprisingly slow FFF of 10- 15 Hz (figure 2) a finding, however, in keeping with their nocturnal lifestyle. The day-active yellowfin tuna, on the other hand, was capable of much higher temporal resolution, resolving light pulse frequencies at up to 45 Hz (figure 2). These results illustrate that the speed of vision is highly dependent on the lifestyle of the fishes and can vary significantly between species.

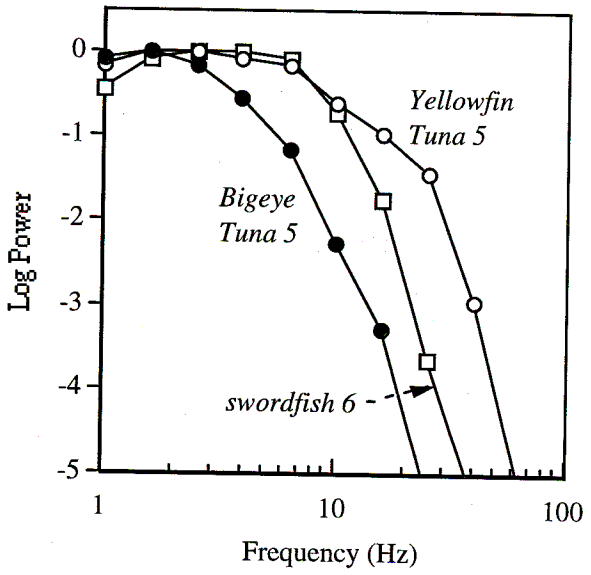


Figure 2: We determined flicker fusion frequency (FFF) in swordfish, yellowfin tuna and bigeye tuna, using the power function over frequency. From visual inspection of the recording trace and the resulting power spectrum of dominant frequencies we determined the frequency at which a response to individual light sources was not detectible any more. This point was usually reached at a power of – 3.5 log units which we then defined to be the FFF. Hence the FFF of swordfish and bigeye tuna presented in figure 2 was found at 8-15Hz, reflecting the dim deep-water habitat of the two species. The shallow-living yellowfin tuna was found to have a higher FFF at 45 Hz.

Marked changes in visual performance from day to night

Shallow-living species like the yellowfin tuna experience a large change in light intensity from day to night. We have discovered the first evidence in pelagic fishes that vision changes accordingly. Eight hour long continuous electrophysiological recordings from pieces of isolated retina showed clear differences in visual function between day and night (figure 3 left). In the night-adapting retina the response to light grew markedly stronger, indicating that the eye increased its sensitivity for vision in dim light. This behaviour clearly reflected an intrinsic clock of the retina, adapting for night vision irrespective of the surrounding light.

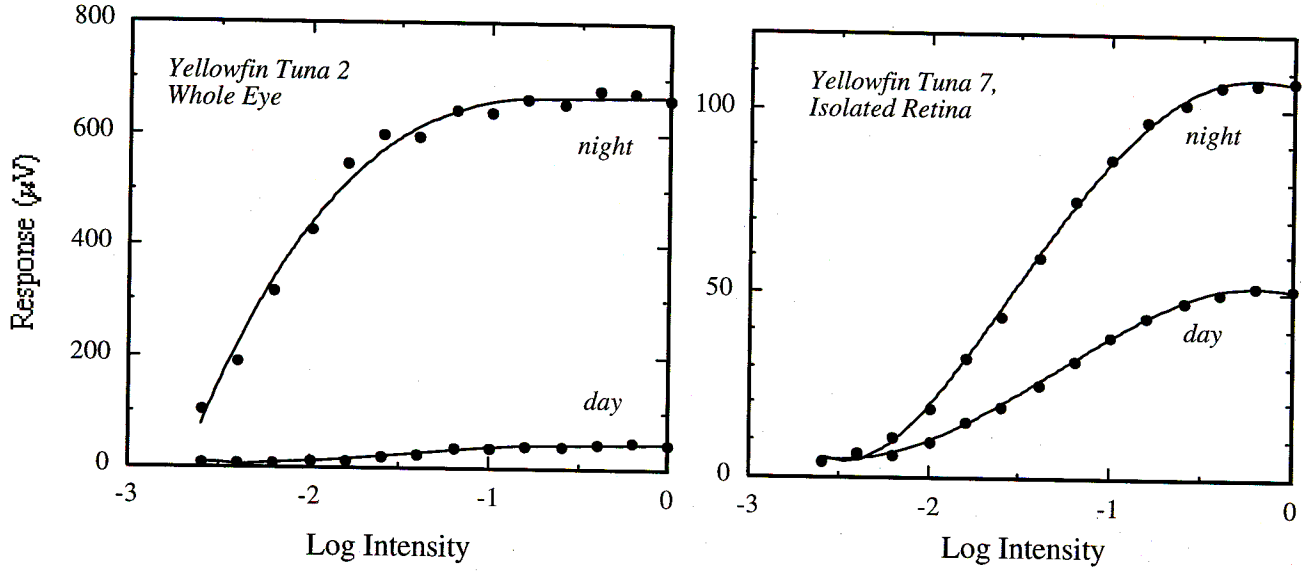


Figure 3: The sensitivity of the yellowfin tuna eye improves significantly during the day-night shift. We found a 10-fold increase in sensitivity during the *in vivo* experiments (left). Surprisingly also the isolated retinae showed a clear circadian shift (right).

A very interesting species-specific difference emerged between the day-active yellowfin tuna and the nocturnal bigeye tuna (figure 3). The circadian adaptation seen in the yellowfin tuna was substantial, reflecting highly different visual capabilities throughout 24 hours. The bigeye tuna, which in recent archival tagging studies has been shown to remain in dim light at depth during the day and ascends with the fading day light, did not significantly change the sensitivity or temporal resolution of its eye in the day-night shift. This result shows the close relationship of visual environment and adaptations of the visual system in different species. The implications of this finding are especially interesting for estimating visual performance at different times of the day with respect to attractiveness and visibility of prey objects.

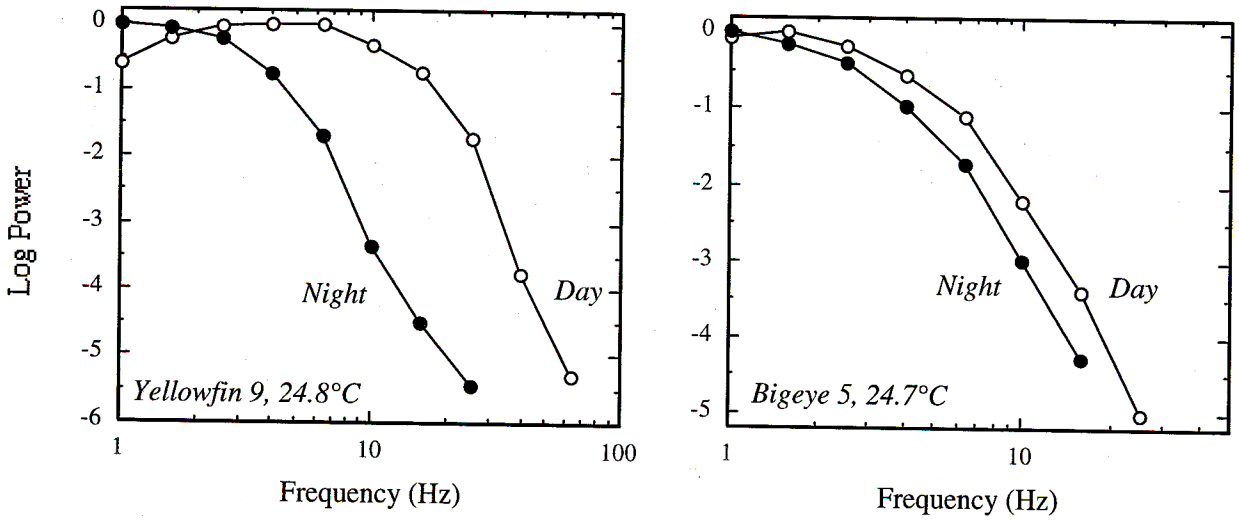


Figure 4: Flicker Fusion Frequency in both the yellowfin tuna (left) and the bigeye tuna (right) measured during the day and at night in isolated retinae. The FFF in yellowfin tuna is markedly reduced at night while the bigeye tuna shows little difference of its FFF throughout 24h.

Colour perception is best in the blue-green

Light entering the ocean is very quickly reduced to a narrow bandwidth of wavelength in the blue-green. A visual system optimally adapted to these conditions should be tuned to this blue-green light which is indeed what we found in a number of pelagic fish such as the striped marlin (figure 5). We also have evidence from the ERG recordings that these species of billfish show two peaks of colour sensitivity, indicating that they might have two visual pigments. The ERG recordings will be complemented by MSP (microspectrophotometry) measurements using frozen samples obtained on board the *Townsend Cromwell* to confirm the presence of colour discrimination in the marlin.

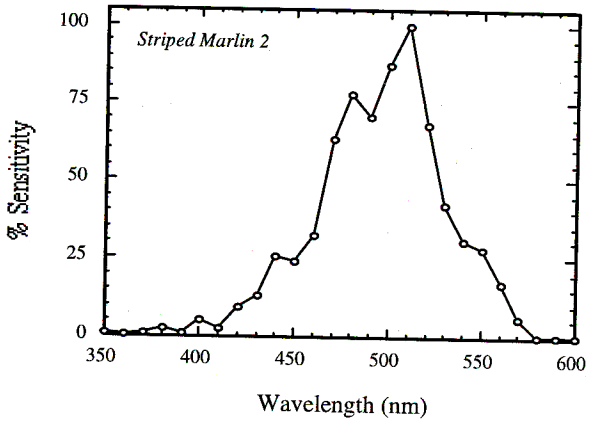


Figure 5: Spectral sensitivity curve of a striped marlin. Best sensitivity is reached in the blue-green waveband while the two peaks indicate that this fish might have two different visual pigments

Retinal heating speeds up vision for high-speed predation

Many pelagic fishes possess ways to maintain their eye and brain temperature above the ambient water temperature when diving into deeper, colder depths of the ocean. The physiology of the heater is well known while the reasons for the need to maintain the eyes at relatively warm temperature has never been tested in pelagic fish. With our ERG recordings we were able to show convincingly that the speed of vision is highly affected by changes in temperature (figure 6), indicating that maintaining warm eyes leads to improved temporal resolution and therefore more accurate vision at high speeds.

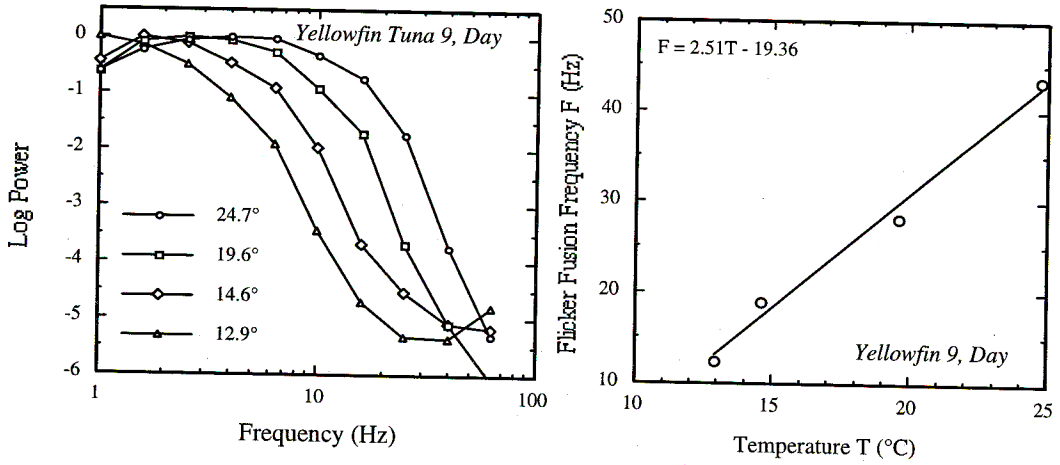


Figure 6: If yellowfin tunas heat their eyes like bigeye tunas, then these data imply that a yellowfin tuna in 15°C water without heating has a flicker fusion frequency of 18Hz, but with heating would have achieved 36Hz. This assumes that the eye temperature is 22°C in 15°C water (as in bigeye tuna).